Claims

[c1] 1.An apparatus for depositing a uniform coating on a planar surface of a substrate, said apparatus comprising:

a)at least one array of a plurality of plasma sources for generating a plurality of plasmas, wherein each of said plurality of plasma sources includes a cathode, an anode, and an inlet for a non-reactive plasma source gas disposed in a plasma chamber;

b)a deposition chamber for containing said substrate, wherein said deposition chamber is in fluid communication with said plasma chamber, and wherein said plasma chamber is maintained at a first predetermined pressure and said deposition chamber is maintained at a second predetermined pressure, said second predetermined pressure being less than said first predetermined pressure; and

c)at least one common reactant gas injector disposed in said deposition chamber for providing a uniform flow rate of at least one reactant gas into each of said plurality of plasmas.

[c2] 2.The apparatus according to Claim 1, wherein at least one of said plurality of plasma sources is an expanding thermal plasma source.

[c3] 3.The apparatus according to Claim 1, wherein said at least one array includes at least one linear array of said plurality of plasma sources.

[c4] 4.The apparatus according to Claim 1, wherein said at least one array includes at least one two dimensional array of said plurality of plasma sources.

[c5] 5.The apparatus according to Claim 1, wherein said first predetermined pressure is at least about 0.1 atmosphere.

[c6] 6.The apparatus according to Claim 5, wherein said first predetermined pressure is about 1 atmosphere.

[c7] 7.The apparatus according to Claim 1, wherein said second predetermined pressure is less than about 1 torr.

[c8] 8.The apparatus according to Claim 1, wherein said second predetermined

pressure is less than about 100 millitorr.

[c9] 9.The apparatus according to Claim 1, wherein said plasma source gas comprises at least one of argon, nitrogen, hydrogen, helium, neon, krypton, and xenon.

[c10] 10.A common reactant gas injector for injecting a uniform flow of at least one reactant gas into a plurality of plasmas generated by an array of a plurality of plasma sources, said common reactor injector comprising:

a)a reactant gas inlet comprising a tubular-walled structure having an interior space through which said at least one reactant gas is supplied from a reactant gas source;

b)a first plurality of orifices proximate to a first plasma, each of said first plurality of orifices extending through said tubular-walled structure from said interior space to an outer surface of said reactant gas inlet, wherein said first plurality of orifices is oriented such that said at least one reactant gas passes from said interior space through said first plurality of orifices and is directed into said first plasma at a first flow rate; and

c)a second plurality of orifices proximate to a second plasma, each of said second plurality of orifices extending through said tubular-walled structure from said interior space to an outer surface of said at least one reactant gas inlet, wherein said second plurality of orifices is oriented such that said at least one reactant gas passes from said interior space through said second plurality of orifices and is directed into said second plasma at a second flow rate, said second flow rate being substantially equal to said first flow rate.

[c11] 11.The reactant injector according to Claim 10, wherein said first plurality of orifices comprises a first predetermined number of orifices having a first linear density and said second plurality of orifices comprises a second predetermined number of orifices having a first linear density.

[c12] 12.The reactant injector according to Claim 11, wherein said first predetermined number is equal to said second predetermined number.

[c13] 13.The reactant injector according to Claim 11, wherein said first linear density

is equal to said second linear density.

[c14] 14.The reactant injector according to Claim 11, wherein each of said first plurality of orifices has a first conductance, and each of said second plurality of orifices has a second conductance, said second conductance being equal to said first conductance.

[c15] 15.The reactant injector according to Claim 11, wherein said first predetermined number is different from said second predetermined number.

[c16] 16.The reactant injector according to Claim 11, wherein each of said first plurality of orifices has a first conductance, and each of said second plurality of orifices has a second conductance, said second conductance being different from said first conductance.

[c17] 17.The reactant injector according to Claim 11, wherein said reactant injector comprises an injector ring encompassing said array.

[c18] 18.An apparatus for depositing a uniform coating on a surface of a substrate, said apparatus comprising:

a)at least one array of a plurality of plasma sources for generating a plurality of plasmas, wherein at least one of said plurality of plasma sources is an expanding thermal plasma source, wherein each of said plurality of plasma sources includes a cathode, an anode, and an inlet for a non-reactive plasma source gas disposed in a plasma chamber;

b)a deposition chamber for containing said substrate, wherein said deposition chamber is in fluid communication with said plasma chamber, wherein said plasma chamber is maintained at a first predetermined pressure and said deposition chamber is maintained at a second predetermined pressure, said second predetermined pressure being less than said first predetermined pressure; and

c)at least one common reactant gas injector disposed in said deposition chamber for injecting a uniform flow of at least one reactant gas into each of said plurality of plasmas, said common reactant gas injector comprising: (i) a reactant gas inlet comprising a tubular-walled structure having an interior

space through which said reactant gas is supplied from at least one reactant gas source; (ii) a first plurality of orifices proximate to a first plasma, each of said first plurality of orifices extending through said tubular-walled structure from said interior space to an outer surface of said reactant gas inlet, wherein said first plurality of orifices is oriented such that said reactant gas passes from said interior space through said first plurality of orifices and is directed into said first plasma at a first flow rate; and (iii) a second plurality of orifices proximate to said second plasma, each of said second plurality of orifices extending through said tubular-walled structure from said interior space to an outer surface of said at least one reactant gas inlet, wherein said second plurality of orifices is oriented such that said reactant gas passes from said interior space through said second plurality of orifices and is directed into said second plasma at a second flow rate, said second flow rate being substantially equal to said first flow rate.

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[c19] 19.The apparatus according to Claim 18, wherein said first plurality of orifices comprises a first predetermined number of orifices having a first linear density and said second plurality of orifices comprises a second predetermined number of orifices having a second linear density.

[c20] 20.The apparatus according to Claim 19, wherein said first predetermined number is equal to said second predetermined number.

[c21] 21.The apparatus according to Claim 19, wherein said first predetermined number is different from said second predetermined number.

[c22] 22.The apparatus according to Claim 19, wherein each of said first plurality of orifices has a first conductance, and each of said second plurality of orifices has a second conductance, said second conductance being equal to said first conductance.

[c23] 23.The apparatus according to Claim 19, wherein each of said first plurality of orifices has a first conductance, and each of said second plurality of orifices has a second conductance, said second conductance being different from said first conductance.

[c24] 24.The apparatus according to Claim 18, wherein said at least one common reactant gas injector comprises an injector ring encompassing said array.

[c25] 25.The apparatus according to Claim 18, wherein said at least one array includes at least one linear array of said plurality of plasma sources.

[c26] 26.The apparatus according to Claim 18, wherein said at least one array includes at least one two-dimensional array of said plurality of plasma sources.

[c27] 27.The apparatus according to Claim 18, wherein said first predetermined pressure is at least about 0.1 atmosphere.

[c28] 28.The apparatus according to Claim 27, wherein said first predetermined pressure is about 1 atmosphere.

[c29] 29.The apparatus according to Claim 18, wherein said second predetermined pressure is less than about 1 torr.

[c30] 30.The apparatus according to Claim 29, wherein said second predetermined pressure is less than about 100 millitorr.

[c31] 31.The apparatus according to Claim 18, wherein said plasma source gas comprises at least one of argon, nitrogen, hydrogen, helium, neon, krypton, and xenon.

[c32] 32.A method of depositing a uniform coating on a planar surface of a substrate, the method comprising the steps of:

a)providing the substrate having the planar surface to a deposition chamber;

b)evacuating the deposition chamber to a predetermined deposition pressure;

c)generating a plurality of plasmas from at least one array of a plurality of plasma sources;

d)injecting at least one reactant gas into each of the plurality of plasmas through at least one common reactant gas injector such that a first flow rate of the at least one reactant gas into a first plasma is substantially equal to a second flow rate of the at least one reactant gas into a second plasma;

e)flowing the at least one reactant gas and the plurality of plasmas into the deposition chamber toward the substrate; and

f)reacting the at least one reactant gas with the plurality of plasmas to form the coating on the planar surface of the substrate.

[c33] 33.The method according to Claim 32, wherein at least one of the plurality of plasma sources is an expanding thermal plasma source having a cathode, an anode, and an inlet for a non-reactive plasma source gas disposed in a plasma chamber.

[c34] 34.The method according to Claim 33, wherein the step of flowing the at least one reactant gas and the plurality of plasmas into the deposition chamber toward the substrate includes the steps of:
a)maintaining the deposition chamber at a second predetermined pressure, wherein the second predetermined pressure is less than a first pressure in the plasma chamber; and
b)expanding the plurality of plasmas from the plasma chamber into the deposition chamber toward the substrate.

[c35] 35.The method according to Claim 32, wherein the step of injecting a reactant gas into the plurality of plasmas comprises:
a)supplying the at least one reactant gas from a reactant gas source to the at least one common reactant gas injector;
b)passing the at least one reactant gas through a first plurality of orifices in the common reactant gas injector proximate to the first plasma and a second plurality of orifices proximate to the second plasma;
c)directing the at least one reactant gas through the first plurality of orifices into the first plasma at a first flow rate; and
d)directing the at least one reactant gas through the second plurality of orifices into the second plasma at a second flow rate, the first flow rate being substantially equal to the second flow rate.

[c36] 36.The method according to Claim 35, wherein the first plurality of orifices comprises a first predetermined number of orifices and the second plurality of orifices comprises a second predetermined number of orifices, and wherein the first predetermined number is equal to the second predetermined number.

[c37] 37.The method according to Claim 35, wherein the first plurality of orifices comprises a first predetermined number of orifices and the second plurality of orifices comprises a second predetermined number of orifices, and wherein the first predetermined number is different from the second predetermined number.

[c38] 38.The method according to Claim 35, wherein each of the first plurality of orifices has a first conductance and each of the second plurality of orifices has a second conductance, wherein the first conductance is equal to the second conductance.

[c39] 39.The method according to Claim 35, wherein each of the first plurality of orifices has a first conductance and each of the second plurality of orifices has a second conductance, wherein the first conductance is different form the second conductance.

[c40] 40.A method of injecting at least one reactant gas into a plurality of plasmas generated by an array of a plurality of plasma sources such that a first flow rate of the at least one reactant gas into a first plasma is substantially equal to a second flow rate of the at least one reactant gas into a second plasma, the method comprising the steps of:

a)supplying the at least one reactant gas from a reactant gas source to a common reactant gas injector;

b)passing the at least one reactant gas through a first plurality of orifices in the common reactant gas injector proximate to the first plasma, wherein the first plurality of orifices is oriented such that the at least one reactant gas is directed into the first plasma at a first predetermined flow rate; and

c)passing the at least one reactant gas through a second plurality of orifices in the common reactant gas injector proximate to the second plasma, wherein the second plurality of orifices is oriented such that the at least one reactant gas is directed into the second plasma at a second predetermined flow rate, wherein the second predetermined flow rate is substantially equal to the first predetermined flow rate.

[c41] 41.The method according to Claim 40, wherein the step of passing the at least

one reactant gas through a first plurality of orifices in the common reactant gas injector comprises passing the at least one reactant gas through a first predetermined number of orifices, and wherein the step of passing the at least one reactant gas through a second plurality of orifices comprises passing the at least one reactant gas through a second predetermined number of orifices.

[c42] 42.The method according to Claim 40, wherein the first predetermined number is different from the second predetermined number.

[c43] 43.The method according to Claim 40, wherein each of the first plurality of orifices has a first conductance, and each of the second plurality of orifices has a second conductance, and wherein the second conductance is different from the first conductance.

[c44] ~~44~~.A substrate having a uniform coating deposited on a planar surface, wherein the uniform coating is deposited by:

a)providing the substrate having the surface to a deposition chamber, wherein the deposition chamber is in fluid communication with at least one array of a plurality of plasma sources, wherein at least one of the plurality of plasma sources is an expanding thermal plasma source having a cathode, an anode and an inlet for a non-reactive plasma source gas disposed in a plasma chamber, the plasma chamber being in fluid communication with the deposition chamber;

b)evacuating the deposition chamber to a predetermined deposition pressure and the plasma chamber to a predetermined first pressure, wherein the predetermined deposition pressure is less than the predetermined first pressure;

c)generating a plurality of plasmas in the plurality of plasma sources and flowing the plurality of plasmas into said deposition chamber;

d)injecting at least one reactant gas through at least one common gas injector into each of the plurality of plasmas as the plurality of plasmas flows into the deposition chamber such that a first flow rate of the at least one reactant gas into a first plasma is substantially equal to a second flow rate of the at least one reactant gas into a second plasma;

e)flowing the at least one reactant gas and the plurality of plasmas into the

deposition chamber toward the substrate; and

f)reacting the at least one reactant gas with each of the plurality of plasmas to form the coating on the surface of the substrate.

Add claims 45-50 C3